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# Short-term Geomorphic Observations in the Nepal Himalayas: Contribution to the Knowledge of Geo-disasters Along a Road Corridor

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## 1 Introduction

In the Himalayas, geo-disasters are recurrent features that generally result from the combination of several hazards (gullying, landsliding, flooding), and affect vulnerable and poorly prepared human communities. This is sadly demonstrated by recent events (1993 Bagmati flood, 2008 Kosi fan avulsion, 2011 Seti khola flood, 2013 Mahakali and Kedarnath floods) that caused a large number of casualties and damages to the property and livestock. Climate-induced hazards are an integral part of the Himalayan geosystem in context of a tectonically active orogen characterized by rapid upliftment and river incision rate, by steep terrain, and locally by weak bedrock. Full understanding of the geo-disasters occurrence requires detailed knowledge of i) interaction between geosystem components, ii) cascading fluxes (both solid and liquid) and iii) retroactive loops that may either reduce or favor geo-disaster development. A short-term geomorphic approach seems adequate for this purpose, but with special focus on hillslope/channel coupling with regard to new road development pattern and design.

## 2 Landslides and study area

Generally considered as the most active process contributing to the denudation of a mountain range like the Himalayas, landsliding occurs at different spatial and temporal scales. Giant rock slope failures are “formative events” that constitute the main components of the Himalayan valley-fills (e.g. Pokhara and upper Marsyandi valleys; Fort 1987a, Fort 2011). Medium-scale, larger frequency landslides also impact both the (forested or not) mountain slopes and river valley bottoms resulting in landslide-dammed lakes and outburst flooding (e.g., Tatopani; Fort et al. 2010). Recent emphasis has been put on “small” size, very frequent landslides affecting the vicinity of major road network, interrupting traffic, causing damages and hampering economic development (Petley et al. 2007).

In this paper, we focus on medium/small-scale landslides of the Middle Kali Gandaki (KG) valley, where the river cuts across the >8000 m high peaks of Dhaulagiri and Annapurna Himal (the deepest gorge in the world). The study zone is very prone to geomorphic instability (very steep slopes, litho-units of varying resistance, the highest amount of rainfall in the Nepal Himalaya; Dahal and Hasegawa 2008). Mountain slopes are either made of rocky spurs with segments exceeding 70° in slope angle, or unstable, debris-covered slopes (<30°) corresponding to older landslide material most prone to remobilization. The valley bottom displays narrow floor with discontinuous patches of aggradational terraces (i.e., late Pleistocene and Holocene age).

## 3 Methodology and study cases

Geomorphic investigations and detailed mapping of geomorphic hazards were carried out (Fort 1987b; White et al. 1987). Repeated observations at selected study sites provided good understanding of the functioning of the landform system at very short time scale (a few hours, years, and decades). We assessed geomorphic changes since the opening of the road up to Mustang District, a road designed and built with little concern in active/dormant geomorphic processes. We illustrate this with two examples (Tatopani, Dana) where slope and debris-flow instabilities are again susceptible to damming the KG valley, inducing backwater flooding and/or triggering landslide dam outburst floods (LDOF), and threaten the road (Fort et al. 2010).

15 years after the Tatopani debris slide (Fig. 1) which dammed the KG river for a few hours, the landslide mass is still affected by shallow translational slides, supplying a flux of debris (pulverized slates) to the KG river, causing undercutting of alluvium fills, collapse of colluvium upslope, resulting in road closures during the monsoon season. Persisting instability may again induce larger slope failures, valley damming, and then submersion of the entire village and new road upstream.

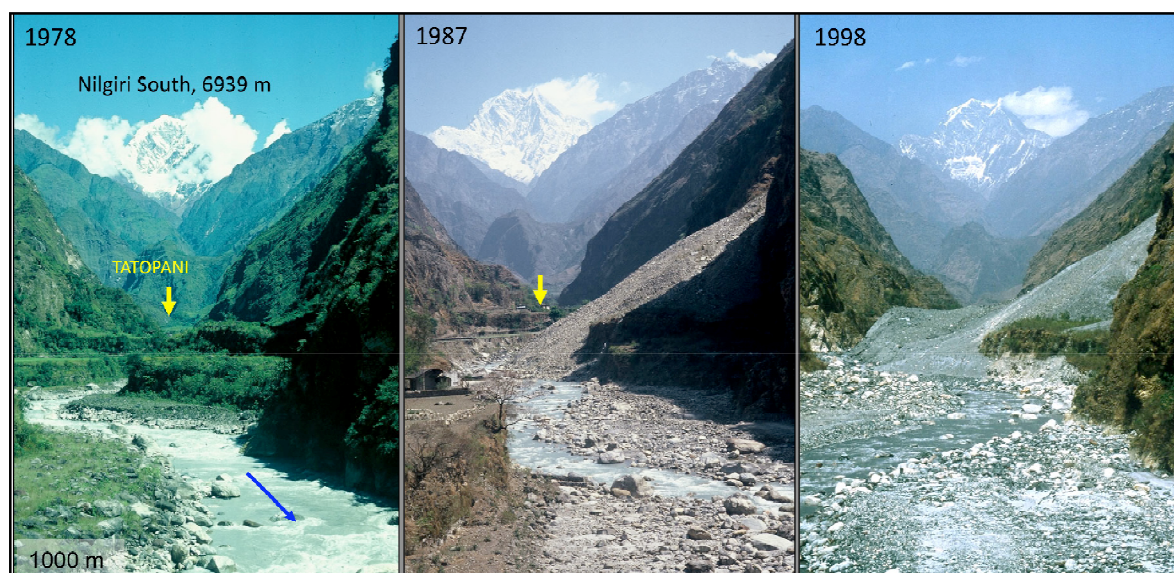


Fig 1. Evolution of the Kali Gandaki (KG) hillslope south of Tatopani (looking upstream). 1978: Tatopani village settled on the lower (+30m) terrace of the KG River; 1987: a first collapse has occurred with rubble accumulation forcing river diversion; 1998, View after the rockslide dam bursting out, with major change of river bottom morphology (© M. Fort).

Although most of the time it is completely dry in its fan, the Ghatte khola (Dana village) is affected by sporadic, destructive debris flows during spring. Generated by a series of landslide dam outburst floods up in the catchment, the debris flows may dam the KG for a few hours like in 1974 (Fort 1974). The design of the new road across the apparently “safe”, large, flat Ghatte Khola alluvial fan may turn out to be more dangerous than initially thought, as shown by the poor design of the bridge (fig. 2), now replaced by a ford reinforced by gabions.



Fig 2. Ghatte khola, very narrow, undersized hydraulic, cross sectional area of the road bridge, that was destroyed by the monsoon flood in late July 2008 (first season following bridge construction) .

#### 4 Concluding remarks

These examples, together with others of similar or greater magnitude (e.g. in Pokhara valley; see Fort 1987), show that road development and subsequent rapid urbanization lead to increasing impacts of geo-disasters on vulnerable populations (inhabitants and travelers) all the more than new road sections are rapidly deteriorating. Continuous updating of natural hazards and assets maps should be recommended

as a straightforward tool to pinpoint and monitor the endangered spots, and prevent any increase in damages and fatalities. These should be completed by hazards and risks maps, hence by preventive structures, regulations and restrictions to settlements and traffic.

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